

HIGH TRANSMITTANCE ALUMINA FOR CERAMIC METAL HALIDE LAMPS

BACKGROUND OF THE INVENTION

5 The present invention relates to high transmittance alumina arc tubes for use in electric lamps. It finds particular application in conjunction with ceramic metal halide arc tubes, and will be described with particular reference thereto. It should be appreciated, however, that the invention is also applicable to other lamp envelopes and shrouds for lamps where high transmittance is desired.

10 Metal halide lamps have conventionally been constructed of a fused silica (quartz) arc tube containing a fill of a light-emitting metal, such as sodium, commonly in the form of the halide, and optionally mercury. The lifetime of such lamps is often limited by the loss of the metal portion of the metal halide fill during lamp operation due to metal ion diffusion, or reaction of the metal halide with the fused silica arc tube, and a corresponding build-up of free halogen in the arc tube.

15 Recently, ceramic metal halide lamps having polycrystalline alumina arc tubes have been developed which provide advantages over quartz arc tubes. U.S. Patent Nos. 5,424,609; 5,698,948; and 5,751,111 provide examples of such arc tubes. Ceramic alumina arc tubes are less permeable to sodium ions than quartz and thus retain the metal within the lamp. They are also able to withstand much higher operating
20 temperatures than quartz arc tubes. While quartz arc tubes are limited to operating temperatures of around 900-1000°C, due to reaction of the halide fill with the glass, ceramic alumina arc tubes are capable of withstanding operating temperatures of 1100 to 1200°C, or higher. The
25 higher operating temperatures provide better color rendering and higher lamp efficiency.

LD 10807

Alumina arc tubes are generally constructed of a number of separate parts. The parts are extruded or die pressed from a ceramic powder mixed with an organic binder. European patent Application No. 0 587 238 A1, for example, discloses a ceramic discharge tube of translucent aluminum oxide. Typically, the parts are tacked together with an adhesive and then sintered to form gas-tight monolithic joints between the components.

Another potential arc tube material for metal halide lamps is sapphire. Sapphire arc tubes have been found to provide improved lamp performances over alumina arc tubes due to increased transmission levels. However, such lamps are expensive due to the cost of manufacturing the monocrystalline sapphire material. There are also problems in sealing of the lamps to prevent loss of the fill material.

Improvements in the transmittance of polycrystalline alumina arc tubes have been found when the arc tubes are chemically polished with an alkali metal borate composition. U.S. Patent Nos. 4,033, 743, and 4,633,137 to Scott, et al. disclose a method of contacting an arc tube body with a molten inorganic borate flux which preferentially dissolves a surface layer of alumina grains. The process does not, however, provide arc tubes with transmittances comparable to sapphire because of microscopic discontinuities, or porous regions, in the arc tube surface. The discontinuities remain, even after polishing, reducing the transmittance of the arc tube.

The present invention provides for an improved ceramic body, such as a metal halide arc tube and method of preparation, which has optical performance characteristics approaching those of sapphire.

SUMMARY OF THE INVENTION

In an exemplary embodiment of the present invention, a method of providing a translucent ceramic body with increased in-line optical transmission is provided. The method includes densifying a ceramic body to form a substantially translucent ceramic body. The densifying process includes heating the ceramic body under a pressure of at least 350 kg/sq.cm . The method further includes physically contacting a major surface of the substantially translucent ceramic body with a molten inorganic flux at elevated temperatures and for a time period sufficient to improve transmittance of the ceramic body. The flux includes an alkali metal borate capable of dissolving the ceramic.

In another exemplary embodiment, an optically transparent densified, sintered polycrystalline ceramic body is provided. The body has a major surface which has been treated with a process which includes heating a ceramic body in an inert atmosphere a pressure of at least 350 kg/sq.cm for a sufficient time to form a substantially translucent polycrystalline ceramic body. The process further includes physically contacting a major surface of the substantially translucent ceramic body with a molten inorganic flux which includes an alkali metal borate capable of dissolving the ceramic at elevated temperatures and for a time period sufficient to improve light transmittance by the ceramic body.

In another exemplary embodiment, a high intensity electric discharge lamp is provided. The lamp includes a discharge vessel which defines a chamber. The discharge vessel is constructed from a polycrystalline material which has been densified by applying sufficient pressure and temperature to reduce pores in the vessel and polished by physically contacting a major surface of the substantially translucent vessel with a molten inorganic flux at

LD 10807

an elevated temperature and for a time period sufficient to reduce unevenness in the major surface. The lamp further includes electrodes sealed into ends of the chamber and a fill sealed within the chamber. The fill includes a ionizable medium for initiating and sustaining a discharge.

5

One advantage of the present invention is that it enables an alumina arc tube with high transmittance to be formed.

Another advantage of the present invention which derives from the ability of the arc tube to transmit light with minimal scattering from the smooth surface and allows for lamps formed from the material to provide a more point source illumination.

Still further advantages of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a side view of a high transmission metal halide lamp according to the present invention;

FIGURE 2 is a side view of an unassembled ceramic arc tube according to the present invention;

FIGURE 3 is an side view of a partially assembled ceramic arc tube according to the present invention;

FIGURE 4 is a side view of the ceramic arc tube of FIGURE 1; and

FIGURE 5 is a plot of luminous flux through an aperture versus aperture size for unpolished and polished lamps.

LD 10807

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

With reference to FIGURES 1-3, a, high-pressure metal halide lamp is provided with a discharge vessel 1, including a high-transmission arc tube or body 10 which encloses a chamber or discharge space 12. The arc tube has its major surfaces physically and chemically treated to provide increased optical transmission in a manner which will be more fully explained hereinafter.

The discharge space preferably contains a fill which comprises at least one metal halide, such as sodium iodide, thallium iodide or dysprosium iodide, in addition to mercury and a rare gas, such as Argon or Xenon. Other suitable fills, for initiating and sustaining an arc discharge, known in the art, are also contemplated. The discharge vessel is enclosed in an outer envelope 14, which is provided with a lamp cap 16 at one end.

First and second internal electrodes 20, 22 extend into the discharge space 12. The electrodes are formed from tungsten, or other known electrode materials. A discharge forms between the electrodes when the lamp is in an operational state. Current conductors 24 and 26 connect the electrodes 20 and 22, respectively, to first and second electrical contact forming parts of the cap 16. In a preferred embodiment, the current conductors each comprise a niobium lead-in portion 27 welded to a molybdenum portion 28 which, in turn, is welded to the respective tungsten electrode. The molybdenum portion may have an overwind of molybdenum (see FIGURE 4).

With particular reference to FIGURES 2 and 3, the ceramic arc tube 10 (not to scale) comprises an outer wall 30, which includes a cylindrical portion 32 with end wall portions 34 and 36 at either end, although other arc tube shapes are also contemplated. Each of the end wall portions defines an opening 38, 40. First and second tubes 42, 44 extend outwardly from the end wall portions 34 and 36, respectively, and are connected to the end walls

LD 10807

around the openings. The current conductors 24 and 26 are received by the first and second tubes. The conductors are sealed into the tubes with seals 46 and 48 to create a gas-tight discharge space.

5 The cylindrical portion, end wall portions and also the first and second tubes are preferably all formed from a polycrystalline aluminum oxide ceramic, although other polycrystalline ceramic materials capable of withstanding high wall temperatures up to 1700-1900°C and resistant to attack by the fill materials are also contemplated.

10 As shown in FIGURES 2-4, the arc tube 10 is readily assembled from separate components, each component corresponding to one of the first and second tubes, end wall portions, and cylindrical portions.

15 The components are fabricated by die pressing or extruding a mixture of a ceramic powder and an organic binder. The components are pre-sintered to about 900-1200°C in air to remove the organic processing aids. Assembly of the arc tube involves placement and tacking of the components. With particular reference to FIGURE 3, the first and second tubes are similarly tacked to the respective end portions with an adhesive and the end portions are tacked to the cylindrical portion. The tacked components are then partially sintered at a temperature of around 1500-1850°C in H₂ to form gas-tight joints. During this sintering, the components shrink to different extents.

20 The differential shrinkage is used advantageously in forming the gas-tight joints. The step of heating in H₂ also increases the density of the ceramic material and reduces the porosity but nevertheless leaves the ceramic with some porosity which affects transmission. Alternatively, the arc tube may be
25 formed with fewer or more components. U.S. Patent Nos. 5,424,609, 5,698,948, and 5,751,111 disclose alternative arc tube bodies which may be used.

The partially sintered Al₂ O₃ arc tube has a few percent of "closed" porosity, i.e. pores within the arc tube which are not open to the

LD 10807

5 atmosphere, and few, if any, "open" pores. At this stage, the tube is about 90% or more of its final density. The closed pores are typically located at the grain boundaries. The tube preferably has an alumina content of about 99.99%, with magnesia (MgO) present at up to 0.5 weight percent, and preferably at about 400-1500 ppm. The magnesia imparts transparency to the finished tube and ensures that most pores remain on the grain boundaries during sintering. Alternatively, other transparent ceramic oxides, such as Y_2O_3 , yttrium aluminate, or mullite ($Al_2O_3 \cdot 2SiO_2$) may be used in place of alumina, or a combination of ceramic oxides may be employed.

10 To form a high-transmittance arc tube, the sintered arc tube is subjected to a two-step process. The first step includes a densifying and/or porosity reducing step process, such as hot isostatic pressing of the arc tube. The second step includes chemically polishing the surface of the tube.

15 In the first step, the alumina arc tube is heated in an inert atmosphere at a temperature of from about 1600 to 1900°C at a pressure of about 5000 psi (350 kg/sq.cm.), or greater, more preferably, from about 10,000 to 30,000 psi (700-2100 kg/sq.cm.) for a period of from about one to about three hours. The pressure is preferably held relatively constant (isostatic) during the densifying process. While pressures of around 5000
20 psi (350 kg/sq.cm.) can reduce porosity, higher pressures are more effective in pore elimination. High pressures are also beneficial if there is residual pressure inside the pores being hot isostatically pressed.

25 Argon gas provides a suitable inert atmosphere, although other inert gases are also contemplated. The sintered ceramic is converted to a semi-transparent polycrystalline aluminum oxide. The pressure eliminates substantially all microscopic porosity which otherwise would reduce the effectiveness of the second, polishing step. The hot isostatic pressing step also strengthens the joints between the components of the arc tube.

LD 10807

During hot isostatic pressing, pores of diameter less than about 5 microns are significantly reduced or eliminated.

Although hot isostatic pressing is a preferred final densifying process, other methods of converting the dense arc tube body unto a translucent ceramic are also contemplated. For example, it is contemplated that the green or partially sintered ceramic body may be contained so that it can be isostatically pressed to translucency in a single step.

In the second step, the outer surface 50 of the arc tube 10 is physically contacted with molten inorganic flux that dissolves alumina at a moderate rate until a surface layer has been dissolved to provide a relatively smooth appearance. About 50 microns may be dissolved in this step. It is preferably in carrying out this type of chemical polishing treatment that the flux composition also be selected so as to dissolve the surface layer of the alumina grains preferentially, rather than dissolve any material at the grain boundaries. This provides a surface flattening action. The preferred fluxing agents should also remain stable in the molten condition at elevated temperatures of treatment of up to around 1000°C.

Useful fluxing agents for providing a relatively smooth and flat surface in the foregoing manner are those which do not tend to produce insoluble reaction products at the molten liquid interface which hinder the dissolving process or form an optical scattering surface having poor in-line transmission. The alkali metal borates provide a general class of useful flux compositions demonstrating the above-mentioned thermal and chemical stability in a molten state. Preferred fluxing agents from this class are those which are readily removed from the polished surfaces by dissolution in a weak acid or other suitable washing process. In particular, sodium and potassium borates, alone or in combination, provide good fluxing agents. Borates of the general form $(M_2O)_n (B_2O_3)_m$, where M is Na, K, or a mixture

LD 10807

of both, and n and m are integers with the ratio of n to m being in the range of from 1:2 to 1:4 are particularly preferred.

The fluxing medium may also contain, in addition to one or more of the borates, a small amount of an alkali metal chloride, such as NaCl or KCl. The chloride is preferably present at a concentration of from about 5-25% and improves removal of the flux after polishing.

To polish the arc tube, it is preferable to carry out the dissolving action in an oxygen containing atmosphere, such as air. In one method, the arc tube is immersed in the molten alkali metal borate or other fluxing agent at moderately elevated temperatures not exceeding approximately 1000°C. This avoids excessive volatilization of the fluxing agent, although the arc tube is capable of withstanding more elevated temperatures if desired. To minimize thermal shock when the treated member is first removed from the molten flux bath it is preferable to return the arc tube to ambient temperature by controlled cooling of the tube, in conventional fashion.

Alkali metal borate fluxes leave a glassy coating on the treated alumina arc tube, which should be removed for optimum in-line transmission. The coating can be dissolved by washing the treated arc tube in a dilute, heated acid solution after it has been cooled.

Alternatively, a glaze polishing method can be used to reduce the surface irregularities. Rather than immersing the arc tube in the molten flux, the flux is produced by coating the arc tube with flux forming materials and then heating to a sufficient temperature to form a flux from the coating. In this method, an alkali borate glass frit can be ground or otherwise formed into a fine powder and formed into a suspension with a suitable carrier liquid, such as methanol. The alkali metal borate is preferably a borate other than lithium borate, with an alkali metal oxide to boron oxide weight ratio in the range of from 1:2 to about 1:4. The frit suspension is applied to the arc tube surface, such as by painting, and then dried to remove all or most of the

LD 10807

carrier. The arc tube can then be heated to a sufficient temperature to melt the glazing material, preferably between about 800°C and 1025°C, for a period of from about 1-2 hours, thereby glazing and polishing the surface.

In one exemplary glaze polishing method, borax, boric oxide, sodium carbonate, and potassium carbonate are mixed. and then heated until melting. The glass material produced is poured into water to produce a frit. The frit is then ground, passed through a screen, and mixed with a carrier, such as a lower alcohol, e.g., methanol or isopropanol. The suspension may further comprise a binder, such as polyvinyl pyrrolidone, and a dispersant, such as glycerol trioleate. The suspension is deposited on an unpolished alumina arc tube and allowed to dry under ambient conditions. The coated alumina tube is then heated to a temperature of between 875°C and 1025°C for 30 minutes to 2 hours to melt the coating and create a flux similar to that formed when a bath of molten flux is used and thereby remove a portion of the underlying alumina surface. The polishing residue is then removed by washing the treated tube in a heated dilute aqueous HCl solution. The surface produced, like that produced by flux polishing, is of a generally flat nature, the polishing process having removed high spots on the individual alumina grains without introducing significant low spots at the grain boundaries.

The polished high transmittance ceramic arc tubes produced in this manner show improved optical transmission over conventional polycrystalline alumina arc tubes. Ceramic metal halide lamps fabricated with the high transmittance ceramic tubes have transmittances approaching those of sapphire arc tube lamps and much superior to those of conventional, polycrystalline alumina lamps.

Without intending to limit the scope of the invention, the following examples show how the polished metal halide lamp compares with conventional metal halide lamps and arc stream lamps.

LD 10807

EXAMPLES

EXAMPLE 1

Hot Isostatic Pressing of Alumina Arc Tubes

Sintered, dense 150 watt ceramic metal halide arc tubes of Lucalox™ were placed into a molybdenum crucible. The crucible was placed into a Conway hot isostatic press and argon introduced at 1000 psi (70 kg/sq.cm.). The arc tubes were heated to about 1750°C at a heating rate of 12.5°C/min, at which time the pressure was 24,500 psi (1722 kg/sq.cm.), and held at a pressure of about 24,500 psi for 1 hour. After pressing, it was observed that pores of about 5 μ or less were significantly reduced or eliminated. While Lucalox begins showing plasticity or creep at about 1400°C, temperatures in excess of 1600°C are particularly suited for decreasing porosity.

EXAMPLE 2

Comparison of Chemically Polished with Unpolished Lamps

Three types of ceramic metal halide lamps (CMH 7009, 700B, and 7001) were prepared. Some of the lamps had arc tubes which were polished by a glaze polishing process, others were left unpolished. The arc tubes for each lamp were first hot isostatically pressed in a heated pressure vessel, as described in Example 1. Then, those arctubes which were to be polished were glaze polished by coating the arctube with a suspension of sodium and potassium borate $[(K_2O) (Na_2O) (B_2O_3)_6]$ in methanol. The coated arctubes were heated to a temperature of about 900°C. This temperature was above the melting point of the glass coating, which was about 850°C, and also above the melting point of the glass coating when some of the alumina has dissolved in the molten glass, which was somewhat higher. The polishing residue is then removed by washing the treated tube in a heated dilute aqueous HCl solution.

LD 10807

The effect of chemical polishing was clearly evident by comparing photographs of the projected image from the polished and unpolished arctubes in lamps. The unpolished arctube, in the operating lamp, appears bright white with no resolved features, while the lamp with the ceramic tube that had been pressed and chemically polished showed the visible plasma.

1) Total lumen measurements.

The total output of chemically polished CMH lamps was compared with that of an Arc stream™ lamp (a quartz metal halide lamp manufactured in Europe by General Electric) and a non-polished CMH lamp in a large integrating sphere. The large sphere was calibrated using a three fiber XMH-60 source. Lumen measurements were taken from all three fibers using the Graseby optronics 371 integrating sphere. The fibers were then measured individually and simultaneously to ensure the detector in the large sphere was operating within its linear region for the lamp measurements. The detector was read using an ammeter and the calibration factor found using the fiber source. The non-polished CMH lamp and the Arcstream lamp were run at 120.0 VAC, while the voltage of the chemically polished CMH lamps was varied so that they ran at the same total wattage output as the non-polished CMH lamps. The total lumen output for the pressed and polished CMH lamps was greater than for the controls.

2) Aperture measurements.

All of the lamps tested were placed in turn in a GE MR20-B1 reflector. The Graseby 371 integrating sphere was placed at the focus of the reflector and the lamp position and sphere position were maximized using the CMH 7001 lamp with a 9mm aperture on the sphere. The non-polished CMH and the Arcstream lamp were run at a 120.0VAC and the polished CMH lamps were run at the same voltages as for the large sphere measurements.

LD 10807

Lumen measurements were taken with 6, 9, 12, and 17.5mm apertures. The results are shown in TABLE 1.

TABLE 1

Aperture Size (mm)	Arcstream Luminous Flux	Old CMH Luminous Flux	Chem pol CMH 7009 Luminous Flux	Chem pol CMH 700B Luminous Flux	Chem pol CMH 7001 Luminous Flux
0	0	0	0	0	0
6	885	587	691	718	680
9	1174	806	922	892	912
12	1571	1070	1174	1259	1058
17.5	2672	1942	2160	2136	1974

FIGURE 5 is a plot of luminous flux through an aperture versus aperture size for the five lamp types.

Because the arc length in the CMH lamp is about twice that of the Arcstream lamp, it was not expected that more light would be obtained in a 17.5mm aperture for the polished CMH than for the Arcstream. However, in the best case, 83% of the light from the Arcstream was obtained using the present chemically polished CMH. Comparing the polished CMH and the normal CMH lamps, a 22% increase in the light into a 6mm aperture was obtained for the best lamps. CRI was higher in the polished bulb 85a than in the Arcstream 80. The results suggest that reducing the arc length to about 5mm or less, a CMH lamp could be used for fiber optic applications.

The invention has been described with reference to the preferred embodiment. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description.

LD 10807

It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218
2219
2220
2221
2222
2223
2224
2225
2226
2227
2228